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INVESTMENT OPPORTUNITY: A SCANNING-ULTRASONICS CUT STOCK MANUFA--ETC(U)
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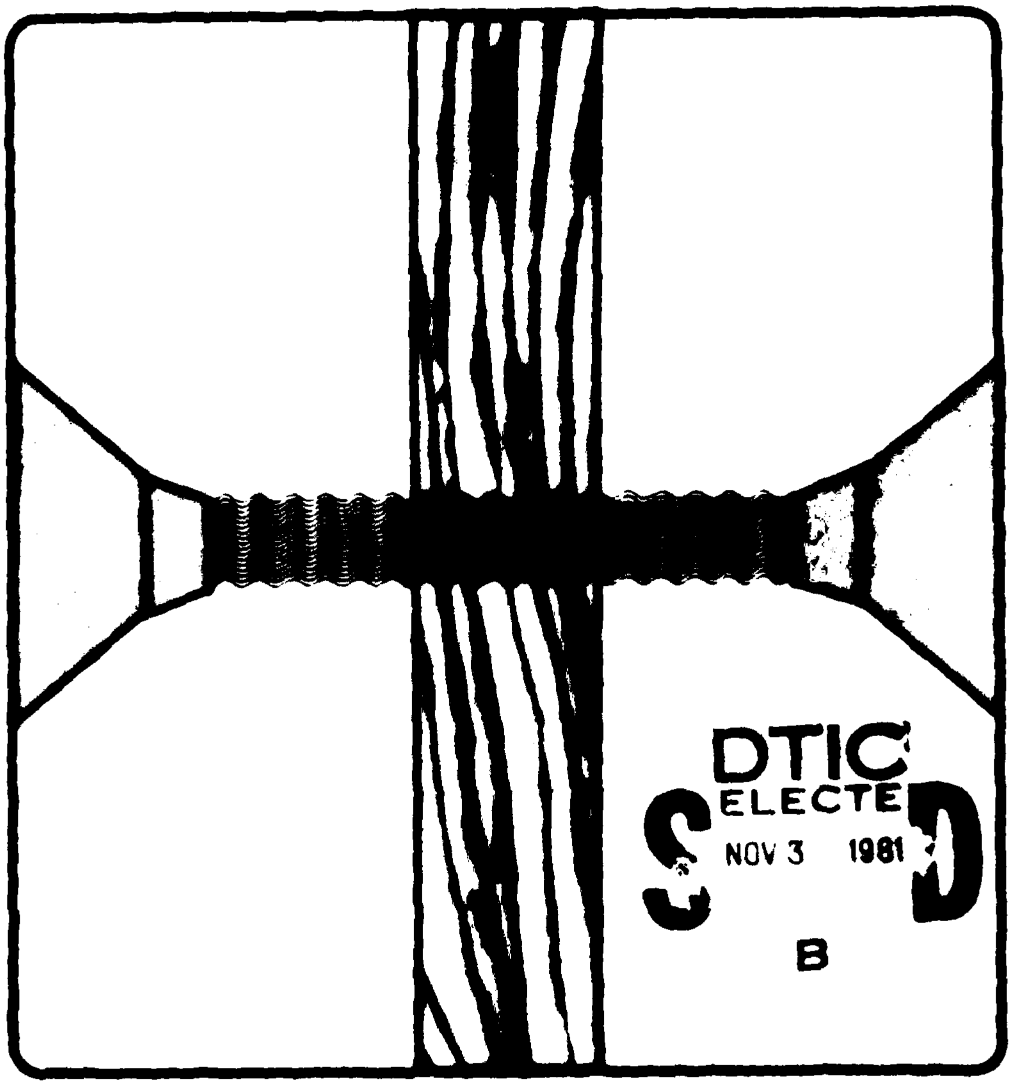
Investment Opportunity: A Scanning-Ultrasonics Cut Stock Manufacturing System



Abstract

Because of the great difference in values between cut stock items and their processing residues, economic methods of cut stock manufacture are highly dependent upon minimization of sound wood waste from cutting operations. For this reason, research was conducted at the U.S. Forest Products Laboratory which developed ultrasonic methods for high speed identification of wood defects and processing control for optimizing clear wood product yield. Problems of applying such technology to commercial practice, however, remain to be solved. Economic analysis indicates that processing costs for such systems could be completely recovered by as little as [illegible] percent improvement in primary product recovery.

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U.S. Forest Products Laboratory

Investment opportunity: A scanning-ultrasonics cut stock manufacturing system, by George B. Harpole and Kent A. McDonald, Madison, Wis., FPL 1981.
8 p. (USDA For. Serv. Res. Pap. FPL 390).

An automated processing system that could function with lumber scanners would provide the potential for high speed and high volume cutting operations, and also provide a basis for significant product recovery gain over machine operator-decisioned operations.
This paper reports the analysis of the economic prospects for such a system.
Keywords: Cut stock, automated processing system, lumber scanners, lumber defect detection, utilization economy.

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Investment Opportunity: A Scanning-Ultrasonics Cut Stock Manufacturing System

By

GEORGE B. HARPOLE, Research Forester

and

KENT A. MC DONALD, Forest Products Technologist

Introduction

About 4 billion board feet of lumber are processed through cutting operations annually for the production of such items as toys, luggage, agricultural implements, door frames, and furniture. The wood raw material is typically of a cutting grade, spotted and streaked with defects precluding the material from production of structural grades of lumber but allowing recovery of clear, sound pieces of wood suitable for production of a variety of high quality consumer goods. Hardwood and softwood shop and moulding grades used typically range in value from $300 to $1,500 per thousand board feet (MBF), before remanufacture. Some turned and shaped furniture items sell for as much as $15,000 to $20,000 per MBF. Residues from such operations typically market for less than the equivalent of $20 per MBF. For these reasons, the most economic methods of cut stock manufacture are highly dependent upon minimization of sound-wood waste from cutting operations.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Italicized numbers in parentheses refer to literature cited at end of this report.

Cut stock manufacture is often begun by ripping shop and moulding grade lumber into full length strips in final product widths, and then crosscutting to random or specified lengths to eliminate defective material. When making products such as door stiles or rails, random length cuttings are often fingerjointed and then again crosscut to obtain specified lengths. Some required widths can be obtained by edge gluing. Other products dictate either rip-crosscut or crosscut-rip procedures depending upon the relative importance of length versus width dimensions of the final products to be produced. With mixed product cutting requirements it is necessary to evaluate each piece for determination of which cutting procedure will yield the largest number of required cuttings possible from the least amount of raw material.

Research was initiated at the U.S. Forest Products Laboratory (FPL) several years ago to develop automated processing systems that could function with lumber scanners providing high speed identification of wood defects *(5)*.[2] The successful development of lumber defect detection by electronic measurements of ultrasonic sound transmissions is an encouraging result of this FPL research *(2-4)*. Not only do such methods provide the potential for high speed and high

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volume cutting operations but also provide a basis for significant product recovery gains over machine operator-decisioned cutting operations *(8)*. Information on the increased yield of cuttings from computer-controlled sawing and cutting decisions is limited; however, it is believed that gains of from 5 to 10 percent in clear wood cuttings can be obtained from any cutting operation. In an edging, ripping, crosscutting operation the gain would be accumulative. That is, assuming a 5 percent gain in clear wood cuttings at each cutting operation, the total gain would be 15.8 percent (1.05 x 1.05 x 1.05).

Electronic defect detection technology has not yet been applied to commercial practice *(3, 4)*. The development of high speed, high volume mechanical systems is necessary to justify the application of such technology. Also, research is needed to determine the potential effect of using a liquid (water and/or other chemical) couplant on dry lumber, the effect on product yields if certain defects are not located (end splits, checks, etc.), and the design and testing of efficient computer-processing programs that can control sawing operations of a mechanical system.

Solving the commercialization problems for ultrasonic defect detection technologies will allow computer decisions to be used for rapid and automated execution of highly accurate crosscutting and ripping operations that will maximize yields of clear pieces of prespecified sizes. Such systems will allow for maximization of either volume or value of cutting yield. This paper reports the analysis of the economic prospects for such a system.

Process Description

Many different processing configurations could incorporate the ultrasonics defect detection system. The hypothetical system described here presents one particular set of possible process options, conceived as probably suitable for automated control of high speed cut stock manufacture (fig. 1). Portions of this hypothetical system, such as the transverse multiple-transducer defect detector system and the computer software required to execute the sawing decisions through sawing control, are not commercially available. Also, automated systems for reliable detection of the extent of lumber end splits have not been developed. Costs for the equipment not yet commercially available are included as best estimates of costs for analytical purposes.

The hypothetical process assumed for analysis is designed to be capable of processing shop lumber in standard sizes ranging from 4/4 to 16/4 inches thick by 4 to 24 inches wide, and 6 to 16 feet long, at an edgewise feed rate of about 50 lineal feet per minute; and to process either rough, S2S, or S4S lumber, preedged and/or unedged of any species. The system prescribes the following sequence of operations: 1) ultrasonic defect scan, 2) profile scan, 3) data interface and computer-controlled cutting decisions, 4) rip and/or crosscut, or 5) crosscut and/or rip.

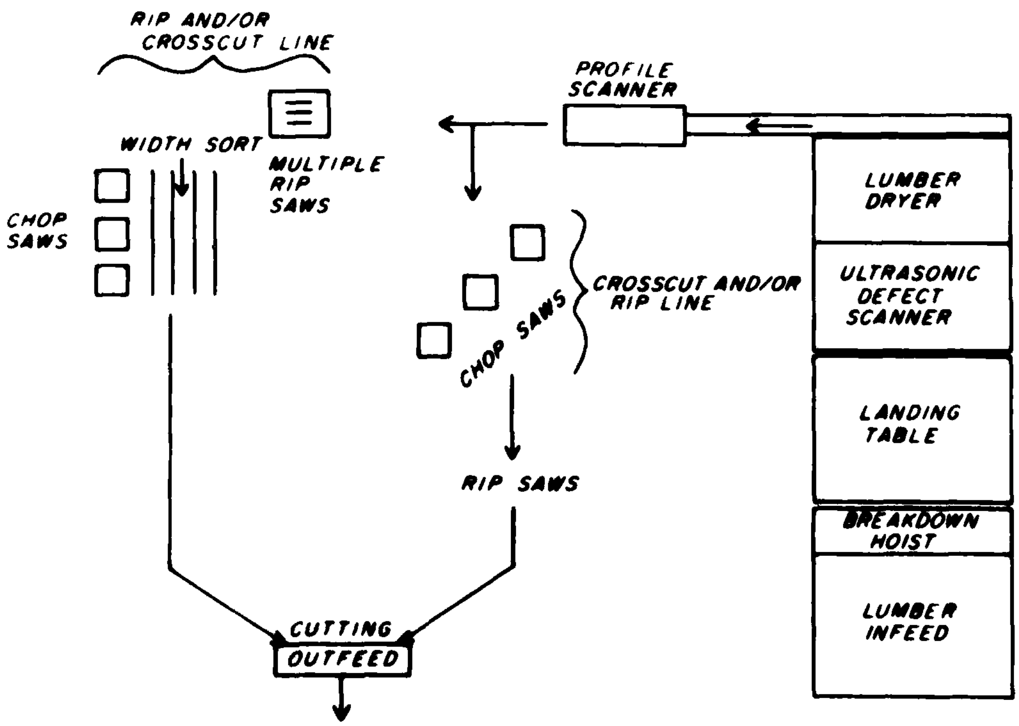

Figure 1.—Flow diagram of an automated lumber cut-up plant using the ultrasonic defect scanning concept. (M 149 122)

Ultrasonic Defect Scanning

Because the grain of clear wood is normally uniform, and defective wood and knots are of different uniformity, the velocity of sound through clear wood is constant and significantly different from that through defective wood or knots. Using an ultrasonic sound transmission technique developed for wood, sound velocities are calculated from transit time data obtained by transmitting sound through wood from a transmitting transducer to a receiving transducer, and measuring the elapsed time. Lumber and transducers must be submerged in water to provide an ultrasonic couplant which is necessary to propagate sound energy into and out of the wood. Water, used as a couplant, makes good contact with rough sawn surface as well as sanded or planed wood surfaces. By moving boards (transversely) edgewise past a series of ultrasonic transducers that span the full board length, a slow scanning speed may be maintained allowing for the scanning of unedged boards at fairly high throughput piece rates.

Profile Scanning

Three separate commercial systems have been developed for optically scanning lumber and describing individual piece profiles. Optical scanning systems are electronic simulations of the human eye which create images dependent upon light reflected from the wood surface back to a receiving lens. The reflected information is then translated into board profile data which can be utilized to position the board in line with rip saw equipment to remove edge wane, only to the extent required to maximize lumber value or volume recovery.

Economic Analysis

Because of the variable nature of cut stock manufacture, lumber throughput rates are not very meaningful. For this reason, processing costs are expressed as cost per 8-hour shift, and then examined on the basis of hypothetical lumber throughputs. Processing and production costs include variable and fixed manufacturing costs, taxes, depreciation, and profits. Total investment requirement for the system is estimated to be about $2 million (table 1). Processing costs (1979 basis) were estimated to be about $3,670 per 8-hour shift for single shift operation, and about $2,530 per 8-hour shift for a two-shift operation. Processing costs do not include the cost of wood, which, when added, yield full production costs.

Discounted cash flow analysis was used to compute *total per-shift processing and production costs (1).* All operating costs are assumed to increase at a rate of 7 percent each year over the facilities' 10-year assumed operating life. *Given costs reflect costs in the first year of operation, 1979. The components of costs represent the average distribution of required revenues to costs, including profits, over the 10 years of assumed operation.* If a higher rate of inflation was used, costs would be lower. For this reason, analysis may be considered pessimistic if a higher rate of inflation may appear appropriate, or optimistic if a lower rate of inflation may appear more likely.

Table 1.—Summary of investment requirements[1]

Facilities investment:	
Buildings (1,200 ft², $20/ft²)	$ 24,000
Package infeed	109,336
Detector infeed and transport	52,400
Ultrasonic detector:	
Tank and accessories	26,650
Electronics and computing	449,250
Board drying section	33,000
Edger machine center	493,700
Trimmer machine centers (2)	272,802
Forklift	21,500
Miscellaneous	17,100
Electrical, 500 hp, $100/hp	50,000
Subtotal	$1,549,737
Engineering at 15 pct	232,466
Contingency at 10 pct[2]	154,973
Total facilities investment	$1,937,176
Working capital investment	100,000
Total investment requirement	$2,037,176

[1] 1979 cost basis.
[2] Contingency to cover freight, sales taxes, etc.

Source: Unpublished engineering economy study prepared for FPL by Ed Williston and Associates, Gig Harbor, Wash.

Investment Requirements

Investment costs are the costs incurred for the purpose of producing future revenues. Investment requirements are of two types: 1) investments to establish the physical facilities needed to manufacture and 2) investment monies required to supply working capital to cover the accumulation of paid-out operating and raw material costs until finished products are sold and revenues recovered (assumed to be 2 weeks). Investment requirements are estimated to be about $2 million (table 1).

Operating Costs

Operating costs include the variable and fixed costs associated with the processing of lumber. Variable costs depend directly upon the volume of lumber processed and are, therefore, often referred to as direct costs. These costs include forklift operation, electrical power costs, as well as lumber costs. For analysis, lumber costs are considered separately and are not included in the operating costs for purposes of estimating processing costs (table 2).

Table 2.—Operating costs

Variable costs:	
Operating supplies	$ 80.00/8-hour shift
Direct electrical ($0.05/kwh)	106.11/8-hour shift
Miscellaneous utilities	30.00/8-hour shift
Subtotal	$216.11/8-hour shift
Fixed operating costs:[1]	
Supervision[2]	$ 19,500/one-shift year
Labor[2]	268,164/one-shift year
Repair and maintenance	125,916/year
Taxes[3] and insurance	38,744/year
Subtotal	$452,324/one-shift year

[1] Fixed operating costs exclude fixed overhead costs such as depreciation, revenue taxes and profit (see table 4).
[2] Supervision and labor costs include 30 percent fringe benefit costs. These amounts are doubled for two-shift operation. See table 3 for crewing and labor cost details.
[3] Accounts for advalorem property taxes, only.

Table 3.—Crewing and labor costs

	Persons per shift	Direct hourly rate	Annual costs
Fork truck operator	1	$ 6.93	$ 13,860
Defect scanner operator	1	8.50	17,000
Offbear and drier tender	1	8.25	16,500
Profile scanner operator	1	8.50	17,000
Transfer tender	1	7.26	14,520
Edger operator	1	8.50	17,000
Chop saw operator	2	8.50	34,000
Offbear and stack	3	6.93	41,580
Relief and cleanup	1	8.16	16,320
Foreman	1	9.25	18,500
Crew, cost per hour	13	$103.14	
One-shift cost per year			$206,280
Fringe benefit cost (30 pct)			61,884
Total cost per one-shift year			$268,164

Source: Unpublished engineering economy study prepared for FPL by Ed Williston and Associates, Gig Harbor, Wash.

Fixed costs are costs incurred independently of the volume of production and include processing labor, supervisory and administrative costs as well as repair, maintenance, insurance, and advalorem tax costs. Labor costs may be argued to be to some degree a variable cost, or to be standby or fixed cost associated with a given throughput capacity (table 3). For analysis, labor costs are treated as fixed costs and separately assessed for effects of changes upon total processing costs (tables 4 and 5).

Processing Costs

Processing costs vary with the number of operating shifts per year. With one complement of supervision and manning requirements sufficient for a one-shift, 250-day operating year, per-shift variable costs (excluding wood costs) will remain constant while per-shift fixed costs (annual fixed cost/number of shifts) will be reduced as the number of operating days per year increases (table 4). That is, per-shift costs will range from $4,538 to $3,098 for 200 to 300 days of operation, respectively, with crewing to run on a one-shift basis. With crewing to run two shifts, per-shift costs will range from $3,107 to $2,144 for 400 to 600 shifts, respectively. Average per-shift processing costs for a one-shift operation, 250 operating days per year, are about $3,674 per shift and about $2,529 per shift for two-shift operation. The sensitivity of these processing costs to changes in various cost components may be assessed from table 5.

Production Costs

Lumber costs need to be added to processing costs to obtain production costs, i.e., the full cost of processing lumber into final products. Introducing the costs of lumber has three cost increasing effects: 1) the cost of lumber increases variable operating costs, 2) the cost of lumber increases the amount of working capital required, thus increasing investment and the profit that must be returned to investment capital—assumed to be 15 percent after taxes, and 3) taxes are increased because any increase in profits will be accompanied by a proportionate increase in taxes paid.

Under the assumption of analysis, full per-shift production costs can be obtained by multiplying the per-shift cost of lumber by 1.0129 and adding the results to the appropriate processing costs (table 4), i.e.,

$$\text{Production cost for one-shift, 200 to 300 shifts per year (\$/8-hr shift)} = \$216 + \left(\frac{\$664{,}500}{\text{Shifts per year}}\right) + (1.0129 \times \text{Cost of lumber per shift})$$

$$\text{Production cost for two-shift, 400 to 600 shifts per year (\$/8-hr shift)} = \$216 + \left(\frac{\$1{,}156{,}600}{\text{Shifts per year}}\right) + (1.0129 \times \text{Cost of lumber per shift})$$

Table 4.—Summary of per-shift processing costs (excluding lumber costs) for one- and two-shift operations with different numbers of shifts per year

	One-shift basis			Two-shift basis		
	200 shifts per year	250 shifts per year	300 shifts per year	400 shifts per year	500 shifts per year	600 shifts per year
	Dollars per shift					
Variable costs[1]	216	216	216	216	216	216
Supervision and labor	1,438	1,151	959	1,438	1,151	959
Fixed overhead costs	823	659	549	412	329	275
Depreciation	631	504	420	315	252	210
Taxes (51.12 pct)	661	529	441	336	269	224
Profits (15 pct after tax)	769	615	513	390	312	260
Total	4,538	3,674	3,098	3,107	2,529	2,144

[1] Variable costs include operating supplies, electrical power, and miscellaneous utility costs.

Lumber Throughput

Lumber will move edgewise through the defect scanner at a theoretical rate of 50 feet per minute. Spacing between pieces of lumber of 1/8 inch or more is sufficient for the defect scanner to recognize individual pieces of lumber. However, the following analysis assumes that lumber will be spaced 4 inches apart, and that the average piece size will be 8 inches wide by 13 feet long. Assuming the defect scanner is the limiting piece of equipment in the process, the system would have a theoretical capacity to process 433 square feet of lumber per minute, 26,000 square feet per hour, and 208,000 square feet per 8-hour shift—if there is no loss of lumber throughput capacity. Only 65 percent of the theoretical maximum was assumed for this analysis. On this basis, the system is assumed to be capable of processing about 135,200 square feet of lumber per 8-hour shift. A 250-shift per year operation would process about 42 million board feet of 5/4-inch-thick lumber per year (table 6), or 169 MBF per 8-hour shift.

The cost of processing 5/4-inch-thick lumber can be estimated as the appropriate per-shift processing cost divided by the estimated volume of lumber throughput, which is $21.74 per MBF for a 250-shift operation (table 7). This is the processing cost per MBF of throughput—the volume of lumber fed into the system and sawn into cut stock and residues. To determine whether the system will profitably process a given size and grade of lumber into a given cutting order more information would be needed, such as percent and value of cut stock recovery, percent and value of residues, and cost of lumber used. However, to assess whether such a system justifies the replacement of an older system, only the processing cost, value of cut stock recovery and residues, and expected increase in recovery efficiency need to be considered. That is, the increase in processing efficiency (Δ percent) needed to offset all processing costs (a clear incentive for replacement) can be calculated by dividing the appropriate processing cost ($\$/MBF_{pc}$) by the difference between the value of the cut stock recovered ($\$/MBF_c$) and the value of the residues ($\$/MBF_r$):

$$\Delta \text{ percent} = \frac{\$/MBF_{pc}}{\$/MBF_c - \$/MBF_r}$$

For example, if the average value of 5/4-inch cut stock is $1,500 per MBF and the value of residues is equivalent to $20 per MBF, a 1.5 percent increase in cut stock recovery will be sufficient to cover all processing costs for a 250-shift operation:

$$1.5 \text{ percent} = \frac{\$21.74}{\$1{,}500 - \$20}$$

Table 5.—Per-shift processing costs at adjusted levels of operating and investment costs (1979 basis), based on a 250-day operating year

Adjusted costs	Processing costs[1]			
	One-shift basis with costs adjusted		Two-shift basis with costs adjusted	
	−20 percent	+20 percent	−20 percent	+20 percent
	Dollars			
Variable costs	3,631	3,718	2,486	2,573
Supervision and labor	3,440	3,907	2,296	2,762
Fixed overhead	3,541	3,808	2,463	2,596
Facilities investment	3,234	4,100	2,309	2,742

[1] Processing costs do not include lumber costs. See table 4 for unadjusted processing costs.

Table 6.—Estimated per-shift and annual volumes of throughput capacity for different thicknesses of lumber[1]

Lumber thickness	Per-shift volume	One-shift basis 200 shifts per year	250 shifts per year	300 shifts per year	Two-shift basis 400 shifts per year	500 shifts per year	600 shifts per year
	Thousands of board feet						
4/4 inch	135.20	27,040	33,800	40,560	54,080	67,600	81,120
5/4 inch	169.00	33,800	42,250	50,700	67,600	84,500	101,400
6/4 inch	202.80	40,560	50,700	60,840	81,120	101,400	121,680
8/4 inch	270.40	54,080	67,600	81,120	108,160	135,200	162,240

[1] Calculations assume equipment feed rates of 50 ft/min with 4-in. spacing between pieces of lumber, an average size of lumber of 8 in. wide by l3 ft long, and operation at 65 pct of theoretical maximum.

Table 7.—Processing cost per MBF of estimated throughput capacity[1]

Lumber thickness	One-shift basis 200 shifts per year	250 shifts per year	300 shifts per year	Two-shift basis 400 shifts per year	500 shifts per year	600 shifts per year
	Dollars per MBF					
4/4 inch	33.57	27.17	22.91	22.98	18.71	15.86
5/4 inch	26.85	21.74	18.33	18.38	14.96	12.47
6/4 inch	22.38	18.12	15.28	15.32	12.47	10.39
8/4 inch	16.78	13.59	11.46	11.49	9.35	7.79

[1] Data calculated by dividing per-shift processing costs (table 4) by the corresponding per-shift estimates of throughput capacity (table 6).

The cost-covering savings is, of course, derived from the difference in values for clear wood cuttings and residues. The lower the differential of value between clear cuttings and residues, the greater the increase in cut stock recovery required to cover processing costs. For example, if the average value of clear wood cuttings from 5/4-inch material is only $500 per MBF and the value of residues is equivalent to $60 per MBF, a 4.9-percent increase in cut stock recovery would be required to cover a processing cost of $21.74 per MBF of throughput.

Summary and Conclusions

Because of the great difference in values between cut stock items and their processing residues, economic methods of cut stock manufacture are highly dependent upon minimization of sound-wood waste from cutting operations. For this reason, research was initiated at FPL several years ago to develop automated processing systems that could function with lumber scanners providing high speed identification of wood defects and cutting operations. The successful development of lumber defect detection by electronic measurement of ultrasonic sound transmissions is an encouraging result of this FPL research. Not only do such methods provide the potential for high speed and high volume cutting operations but also provide for significant product recovery gains over machine operator-decisioned cutting operations.

Electronic defect detection technology has not yet been brought into practice. Applications research is needed for the development of high speed, high volume mechanical systems; to determine the potential effect of using a liquid transducer couplant on dry lumber; to determine the effect on product yields if certain defects are not located (end splits, checks, etc.); and to design and test efficient computer-processing programs that can control sawing operations of a mechanical system.

Many different processing configurations could incorporate the FPL ultrasonics defect detection system. On the basis of one possible system design, economic analysis indicates that processing costs may run from about $8 to $34 per MBF of throughput, depending upon annual throughput volume. Also processing costs for such a system could probably be recovered by as little as a 1.5 percent improvement in primary product recovery.

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